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Appraisal of the Army's Facilities: Managerial Implications, Value Measures, and Computational Methods

by
Osman Coskunoglu

Concern has developed that the current way of determining the replacement value of Army facilities leads to an underestimation of their value. This study examines the managerial implications of valuation and evaluates some appraisal techniques in light of the Army's evaluation needs. Recommendations are made regarding the development of a valuation tool to meet the facility manager's needs.

An apparent concensus among professional appraisers is that there is neither a single correct value measure nor a universally applicable method of facility valuation. Both the measure and the computation method must be consistent with the logic behind the purpose for which they will be used.

Four value measures with potential application in the Army were identified and assessed: (1) replacement cost (RC), (2) duplication (reproduction) cost (DC), (3) optimal facility cost (OFC), and (4) value in use (VU). Five methods can be used to compute these value measures: indexation, unit costing, regression, proportionment, and expert assessment.

The specific alternatives recommended in this study, in order of priority, are: (1) compute DC using a formula given in Chapter 4 (Eq 5), (2) develop an expert system to estimate OFC, (3) compute RC using OFC as the base. A comprehensive effort by the Army to develop these methods would be beneficial in explaining the evolution of facilities cost over time, improving life-cycle cost analyses, and providing effective management for the Army's huge inventory of facilities.

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FOREWORD

This work was performed for the Office of the Chief of Engineers (OCE) under the Operations and Maintenance, Army (OMA) project "Responsiveness Analysis of Military Programs (RAMP)." The OCE Technical Monitor was Mr. Richard Nelson, DAEN-ZCP-B.

The work was conducted by the Facility Systems Division (FS) of the U.S. Army Construction Engineering Research Laboratory (USA-CERL). Dr. Coskunoglu is an Associate Professor in the College of Engineering, University of Illinois at Urbana-Champaign. Mr. Alan Moore was the USA-CERL Principal Investigator. Dr. Michael J. O'Connor is Chief, USA-CERL-FS. The technical editor was Dana Finney, USA-CERL Information Management Office.

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APPRAISAL OF THE ARMY'S FACILITIES: MANAGERIAL IMPLICATIONS, VALUE MEASURES, AND COMPUTATIONAL METHODS

1 INTRODUCTION

Background

Replacement costs of Army facilities currently are valued at approximately $174 billion. Replacement values of Army facilities are adjusted annually by the U.S. Army Facilities Engineering Support Agency (FESA) at Fort Belvoir, VA.* Army facilities (real property) values are listed in the Real Property Inventory (RPI) residing in the Integrated Facilities System (IFS). These values are based on acquisition cost plus any capital improvements made to the facility after acquisition. To determine replacement costs of Army facilities, FESA relies on facility unit costs per facility category (contained in Army Regulation 415-17[1]), which are adjusted for inflation to the proposed midpoint of construction using the *Engineering News Record (ENR)* cost index. A growing concern is that this method underestimates facility value--especially in light of the increasing sophistication and advanced technology that must be incorporated into a modern Army's facilities.

With the aging of facilities and increasing attention directed toward their replacement, accurate knowledge about the magnitude of the potential replacement program will be required to secure adequate funding. A better value measure than exists now is needed to achieve the necessary accuracy in estimating replacement facility cost and value. To find such a measure, the U.S. Army Corps of Engineers (USACE) asked the U.S. Army Construction Engineering Research Laboratory (USA-CERL) to examine professional real estate appraisal methods and assess their potential for valuing Army facilities.

Objective

The objective of this study was to identify and evaluate potential value measures that can be used to assess the facility cost and value of Army real property.

Approach

Information was gathered through a literature search and interviews with USACE personnel at FESA, the Office of the Assistant Chief of Engineers (OACE) and the Directorate of Engineering and Construction (CEEC). The information was reviewed by the Engineering Division at FESA and the Real Property Management Activities (RPMA) Resources Branch (DAEN-ZCF-R) at OACE. Reviewers' reactions and comments were considered and incorporated into this report.

*After this study was completed, FESA was combined with other elements into the U.S. Army Engineering and Housing Support Agency (USAEHSC).

[1]Army Regulation (AR) 415-17, *Cost Estimating for Military Programs* (Headquarters, U.S. Department of the Army, 15 February 1980).

Scope

This study represents research into valuing methods that could serve as management tools with potential application to the Army. It is not intended to develop a new measure or guidance nor to offer ideas on how to improve methods for determining when to replace Army facilities. This research applies to all elements involved in real property replacement decisions at the installation, Major Command, and Headquarters levels.

2 MANAGERIAL RELEVANCE OF APPRAISING THE ARMY'S FACILITIES

The focus of this study can be put into proper perspective through the reasoning of Frederick Babcock, a noted authority in the appraisal field:[2]

> The very first principle that controls a good appraisal is that the purpose of appraisal must be taken into account in the process. Usually appraisals are ordered to make some private or governmental decision possible. The appraisal must serve that purpose. An appraiser should make certain that his valuation is carried out in such a manner that the purpose is served in his answers and estimates. *The narrow view assumes that each property has a value and that the valuation function extends no further than to find the value. But there is no such thing as the value of a property. The valuation function should embrace the estimates and analyses needed to solve very real business and government problems.* Simply calling the current market is not good enough. The problems that lie behind the requests for appraisals must be taken into account in the very process itself. Appraisal is not an end in it self. Appraisals are to be used for serious purposes and for making reliable decisions. An appraisal that merely conforms to some abstract definition of value is quite likely to be inadequate and not acceptable.
>
> *Rote methods will often completely miss the goal. There is no single correct [method] to appraise.* Any logical line of reasoning properly related to the purpose of appraisal is a correct method. [Emphasis added]

An appraisal is usually necessary to reach a decision. The decision, in turn, is needed to solve a problem. These conditions form the underlying premise of this study. Therefore, before discussing valuation methods, it is essential to identify the purposes and decisions germane to the Army's facilities appraisal.

Operations, Maintenance, and Repair (M&R) Funding

It can be postulated that the M&R cost of a facility is proportional to a value measure of that facility. It is intuitively appealing to expect higher M&R expenditures for facilities with a greater "value." However, this postulate may lead to erroneous results.

M&R costs of a facility often depend on many factors. For example, M&R costs of a road depend on the climate. Since a road located in a severe climate requires higher M&R costs and since M&R costs are postulated to be proportional to the "value" of the road, the conclusion is that the road must value higher than one in a region where the climate is mild. This meaningless conclusion can be alleviated to a degree by the averaging effect when a group of facilities' values is considered and only if the following assumption approximately holds true.

[2]F. M. Babcock, "Basic Valuation Principles Revisited," *Valuation*, Vol 22, No. 1 (June 1975), pp 8-22.

Assumption 1: the number (or amount or magnitude) of facilities at one extreme end of a factor affecting M&R costs is equal to the number of facilities at the other extreme. (For example, the amount of road surface in severe climate regions is equal to the amount in mild-climate regions.)

Does a facility that has been historically well maintained and repaired value higher than an identical facility that has been neglected? The intuitive answer is "yes." However, this response has two implications: (1) including historical M&R costs in the value measure will increase the value of a facility over time, implying that M&R costs of the facility increase with age and (2) historically better maintained facilities will require higher M&R costs in the future.

Neither of these implications is meaningful. M&R is necessary to keep the condition of a facility at an acceptable level. These expenditures do not necessarily increase the value of a facility proportional to the amount expended. For example, consider two buildings of the same age. One may be well maintained over its lifetime, the other may be neglected until some recent comprehensive M&R. Buildings may appear to be in the same condition, even though the first one may have a higher historical M&R cost. Essentially, residents of the second building have suffered the consequences of historically poor M&R, but not a lesser value of the building. Therefore, the historical cost of M&R should not be included in a value estimate of a facility. On the other hand, a consistently neglected facility also loses some of its value. Hence, the following assumption should also hold.

Assumption 2: all facilities have been operated, maintained, and repaired properly and approximately at the same level.

The above arguments do not apply to major repairs and changes in the facilities. Modernization, renovation, and rehabilitation (i.e., renewal) activities sometimes add to the utility, and therefore to the value of a facility. However, it is not clear if such improvements increase the M&R requirements of a facility. A modern but expensive heating, ventilation, and air-conditioning (HVAC) system, for example, may provide savings in future energy and M&R costs. In contrast, a modernization activity such as installing microcomputers and networking systems in a building is likely to increase M&R costs in subsequent years. The only way to overcome this dilemma is to separate major additions from repairs and include these additions in the value computation. Hence, a third assumption must hold.

Assumption 3: renewal activities decrease the difference between an existing facility and its contemporaries, thus increasing the value of the former. This situation, in turn, increases M&R costs.

The value of a facility may appear to be decreasing because its original utility is losing significance. This loss of significance may be caused by either of two developments: (1) the original function of the facility may be no longer essential or (2) the facility may be unable to serve its intended function effectively because it cannot accommodate new requirements. Can it be concluded that, in these cases, the value of the facility decreases, and therefore requires less M&R funds? It can be argued that a facility is composed of certain components that need M&R no matter what the facility's significance may be. It is also possible to argue that facilities which are losing significance or cease to be essential are facing replacement, so that it is not prudent to waste money on M&R of these facilities. There is no absolute answer in this case; the decision is a matter of policy. However, an extreme case requires emphasis. In the Army, there are complaints that some installations do not demolish underused or vacant buildings that

have been mothballed. These buildings, it is claimed, waste operational costs. Therefore, even though it is debatable, the following assumption is necessary.

Assumption 4: a facility's M&R funds decrease as the facility loses its significance and utility.

A supporting point for this assumption is the change in function of the facility. For example, suppose a hangar is no longer needed, either because aircraft are no longer landing in that location or the hangar cannot accommodate new aircraft maintenance requirements. The hangar may be assigned to another use, say a depot, which requires less M&R funding.

It is important to emphasize again that the intention of this study is neither to justify nor defend these assumptions. However, M&R funds can be tied to a value measure of the facilities as long as these four assumptions are acknowledged explicitly. Furthermore, the value measure to be used as a basis for predicting M&R costs should be consistent with these assumptions.

Planning for Renewal

For this study, the definition of the term "renewal" is stretched beyond its usual meaning: it is used as a general term that may mean modernization, rehabilitation, renovation, or replacement. Renewal is a policy to be considered when the existing facility's physical and/or functional condition is below an acceptable level. In evaluating this policy, different measures of value are needed.

Consider replacement policy. Such a policy is justified in either of the following two situations: (1) a new facility may save enough M&R costs to justify its initial costs or (2) functional and comfort amenities of the new facility may require or justify the additional costs of the new replacement facility. In either case, the existing facility may have to be demolished, or it may be used for another purpose. In the second case, from the cost of the new facility, the installation will gain two facilities. Therefore, the facility's secondary use value must be considered in the renewal decision process along with the cost of the new facility. The former value is the same as the one used in M&R funding. Both value measures are essential in evaluating the optimal choice among rehabilitation, renovation, and replacement.

It is important to observe the change in the value measure of an existing facility after renewal. In the arguments leading to assumption 3 above, it was claimed that renewal increases the functional utility, hence the value of the facility. Does that necessarily mean the M&R costs will also increase? The answer to this question is not clear. In general, it is true that more recently built facilities incur higher M&R costs because of better technological, functional, and comfort services. Renewal of a facility in effect makes the building "younger" by closing the gap between its original and current designs. Stated another way, renewal reduces initial design deficiencies. Failure to increase M&R funds of a renewed facility would contradict the postulate that M&R costs are proportional to a value measure. Therefore, assumption 3 also is relevant when renewal policies are considered.

To summarize, renewal policy analysis requires two different value measures. One is the same as the measure used in funding M&R. The other is the cost of a facility serving the same purpose as the existing facility but built using current technology and according to current standards and requirements. Complicating the determination of this

cost is the need to account for those value aspects attributable to design, general layout, use of space, etc., that to a great extent determine the value of a facility.

Other Relevant Managerial Functions

A value measure for the Army's facilities may be necessary in three additional situations: requirements planning, relocation of facilities, and general management.

To estimate future funds necessary to construct facilities similar to existing ones, a value measure of those facilities and their rate of value increase are needed (i.e., requirements planning). Current costs of replacing facilities form the basis of this measure. To forecast future costs, however, in addition to predicting the inflation rates, it is necessary to predict the changes in standards, requirements, and available technology, which is difficult. The same situation would be true for facilities relocation.

In the area of general management, organizations often would like to know the worth of their assets. In addition to tracking annual changes in the worth of the assets, a value measure makes it possible to assess the effects of endogenous (e.g., physical depreciation) as well as exogenous (e.g., functional obsolescence and inflation) factors on the assets.

3 VALUE MEASUREMENTS

The value measures that can be used for Army facilities (excluding land) are limited. These facilities have neither an income generation capability nor a market value. Therefore, only two concepts apply: the facility's cost and its functional usefulness. Four value measures based on these concepts are defined and compared in this chapter.

Duplication and Replacement Costs (DC, RC)

The concept of duplication (reproduction) or replacement cost is often used as a real property measurement. Uses include appraisals for insurance purposes and rate-setting for public utilities. Several variations of this concept have been developed within the accounting and appraisal fields. However, there are no universally accepted definitions or computational methods. The terminology has become confused because each organization (including the Army) develops its own definitions. It is outside the scope of this report to clarify this issue. For this discussion, reference is made to the definitions given by the American Institute of Real Estate Appraisers and the Society of Real Estate Appraisers.[3] These definitions are repeated almost verbatim from this source and, in general, are accepted as standard in the field.

Reproduction (Duplication) Cost (DC)

DC is defined as the cost of construction at current prices of an exact duplication or replica using the same materials, construction standards, design, layout, and quality of workmanship, embodying all the deficiencies, superadequacies and obsolescence of the subject building.

Reproduction (Duplication) Cost Less Depreciation

This entity is the cost of reproduction new at current prices less a deduction for depreciation. Since the reproduction cost estimate embodies functional obsolescence, the deduction for depreciation requires the measurement of functional obsolescence for valuation purposes. A measure of functional obsolescence can be estimated by comparing reproduction cost new to replacement costs.

Replacement

Replacement is the substitution of a capital asset that has become exhausted or inadequate with one of fundamentally the same type or utility. If the cost of the substitution is greater than the value of the asset replaced, the difference is a betterment. Minor replacements are in the nature of repairs--that is, expenditures for articles or labor that do not increase the original value of that which is replaced. The ordinary use of replacement suggests improvement.

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[3] American Institute of Real Estate Appraisers/Society of Real Estate Appraisers, *Real Estate Appraisal Terminology*, compiled and edited by B. N. Boyce (Ballinger Publishing Co., Cambridge, MA, 1981).

Replacement Cost (RC)

RC is defined as the cost of construction (at current prices) of a building having utility equivalent to the building being appraised, but built with modern materials and according to current standards, design, and layout. Use of the RC concept presumably eliminates all functional obsolescence, and the only depreciation to be measured is physical deterioration and economic obsolescence.

Replacement Cost Less Depreciation

This factor is the cost of replacement new at current prices less a deduction for depreciation. The deduction for depreciation is the total loss of value arising from physical, functional, and economic causes.

Explanation of Terms

In the above definitions, "new property" refers to a facility designed and built according to the current standards, using the current technology and material, and at current prices. The term "new" does not necessarily mean "just brought into being."

From these definitions, it is clear that DC is equal to RC when the facility is new. It may appear that DC is an irrelevant figure since facilities generally are not replaced with exact replicas. However, DC measures the material worth of an existing facility and is meaningful in assessing the loss associated with demolition. For this reason, DC is used for insurance purposes (i.e., to assign a value to an object and thereby determine an appropriate premium). Furthermore, DC can be compared with RC to assess the functional obsolescence of an existing facility.

Optimal Facility Cost (OFC)

An "optimal facility" is defined as the best possible design for a specific function, given standards and requirements, but without considering costs. It is a hypothetical facility reflecting the state-of-the-art technology for its purpose. The optimal facility, therefore, can be perceived as a norm against which other facilities are measured. The optimal facility cost constitutes an upper bound on the replacement cost.

Value in Use (VU)

Value of a property can be defined by the market (i.e., market value) or by the income generation capability (i.e., income value) of the property. For certain kinds of properties (e.g., Army facilities, publicly owned properties, specialized factories, churches), there is neither a market nor do they generate income. In these cases, the subjective value of the property to a particular owner becomes relevant. A formal definition of this kind of value, called a value in use (VU) is: "the value of an economic good to its owner-user which is based on the productivity (privacies in income, utility, or amenity form) of the economic good to a specific individual; subjective value. May not necessarily represent market value."[4]

[4]American Institute of Real Estate Appraisers/Society of Real Estate Appraisers.

Comparison of DC, RC, VU, and OFC

At the time of acquiring a property, the owner accepts the cost of such ownership. Therefore, it can be presumed that, according to the owner, this cost is equivalent to the utility, amenities, or satisfactions that will be received from the property. This assumption serves as the basis for the idea that this cost measures the owner value, hence the VU. Therefore, when the property is new, the RC, DC, and VU are equal to each other. OFC, however, is higher at this point in time. The difference between OFC and the others reflects the technology that is not used in the current design.

As time progresses, four developments occur:

- Technology advances
- Functional or other requirements, policies, and standards change
- Facilities change
- Prices change.

These developments explain the changes in RC, DC, OFC, and VU of a facility over a time horizon (Figure 1).

Advances in technology are fully incorporated into OFC, but only partially into RC. DC and VU are not affected by this phenomenon.

The changes in requirements, policies, and standards may affect the design of new facilities as well as the utility of the existing facilities, hence RC, OFC, and VU. This effect depends on the nature of the changes. For example, if a new technological necessity arises or new environmental standards are imposed, then RC and OFC are likely to increase while VU will decrease. Certain standards or policies may eliminate certain types of facilities from future construction plans. This situation renders RC meaningless; OFC and VU remain unchanged. In any case, DC remains unchanged.

The existing facilities can change as a consequence of endogenous (e.g., physical deterioration) and exogenous (e.g., a new technology may render the existing facility obsolete) factors. These changes either increase or decrease DC and VU, but do not affect RC and OFC. For example, renewal increases DC and VU.

Another factor affecting these variables is depreciation. There are two types of depreciation: physical and functional. Physical depreciation is the deterioration of an existing facility due to aging. Functional depreciation refers to the deficiencies, other than physical deterioration, that impair utility in the existing facility compared with a replacement facility. Both kinds of depreciation can be curable or incurable. Proper M&R eliminates curable physical depreciation. Renovation, rehabilitation, and modernization can eliminate the curable functional depreciation. Therefore, it is the incurable physical and functional depreciation that accrue over time, and both cause VU to decrease.

The final effect of time to be considered is the change in prices. The general inflation rate affects all four measures in the same way. Specific price fluctuations are the ones which are important to identify. Two assumptions were made in this study, neither of which is totally dependable. Nevertheless, they are plausible and greatly simplify the subsequent analyses.

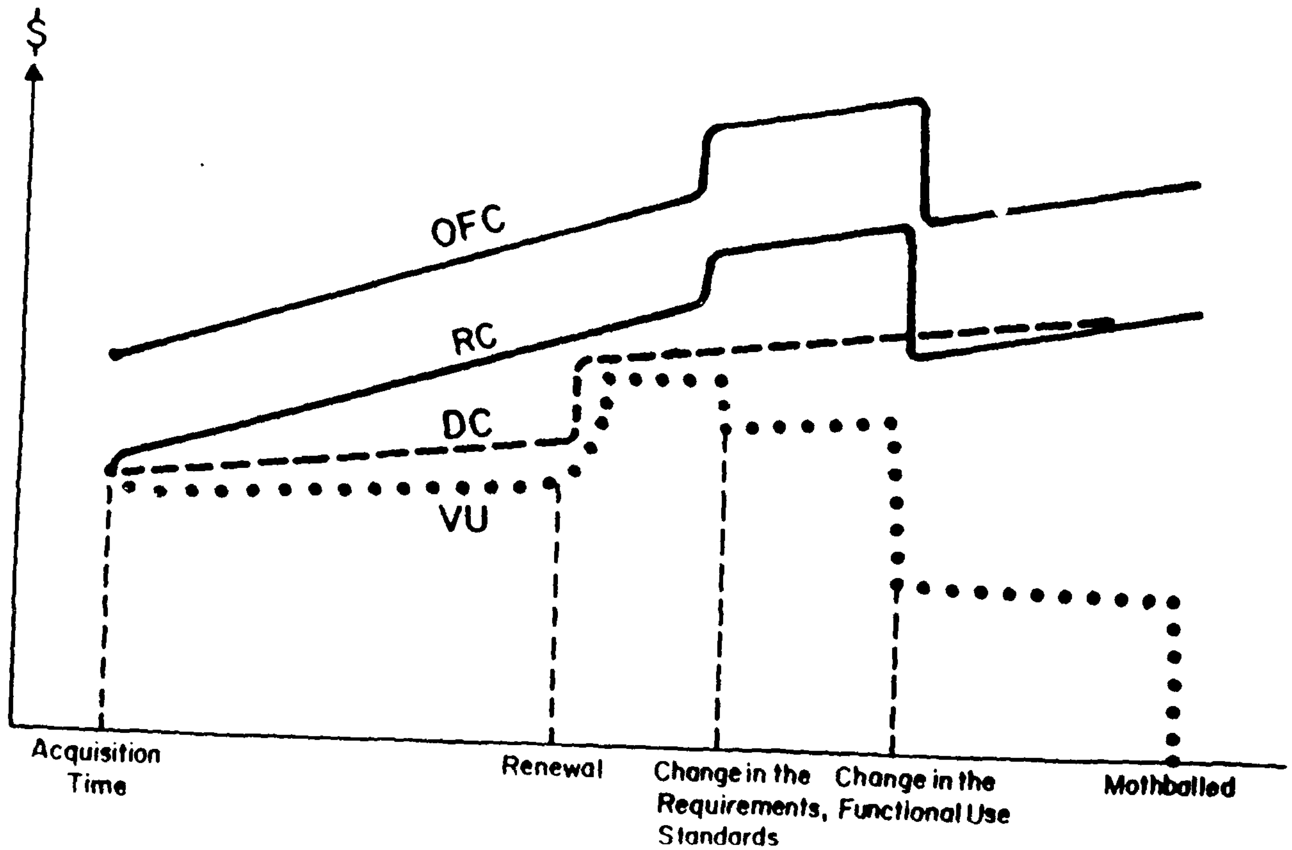

Figure 1. Evolution of value measures over time.

Inflation Assumption 1: adoption of a new technology always increases the cost. That is, technologies (e.g., computers) that decrease in cost over time are rare; these technologies are considered only after their prices stabilize.

Inflation Assumption 2: the effect of new construction technology on construction costs is negligible compared with the general inflation rate.

Summary of Value Measures

Four value measures have been defined: RC, DC, VU, and OFC. The first three are the same when the facility is new. Then, as time progresses, these measures are affected differently due to changes in technology, requirements, standards, policies, prices, and depreciation. Figure 1 depicts the evolution of these four measures over time. From Figure 1 and the above discussions, the following remarks can be made:

1. (OFC - RC) reflects the gap between existing state-of-the-art technology and the implemented technology.

2. DC remains constant as long as the original facility receives no physical alteration.

3. If a facility is used for a purpose different than its initial one, DC becomes meaningless.

4. In general, the difference of (RC - DC) reflects the incurable as well as curable functional depreciation.

5. Right after the time of renewal, the result of (RC - DC) reflects the incurable functional depreciation.

6. (DC - VU) reflects the functional and physical inadequacies of the facility according to its current use and compared with the initially intended use.

4 METHODS OF COMPUTING THE PROPOSED VALUE MEASURES

Chapter 3 defined four value measures (DC, RC, OFC, and VU) and discussed their interrelationships and managerial implications. In this chapter, alternative computational methods are proposed for these four value measures. As indicated in Chapter 2 there is no single correct method. The proposed methods, however, satisfy two conditions:

1. Logical consistency: the logic behind the computational method must be consistent with the definition of the measure. It must also be in line with the logic of the managerial functions to be supported using the measure.

2. Computational accuracy: the computational method's accuracy depends not only on the precision of the method, but also on the availability and reliability of data required by the method. Therefore, the existing data realities must be considered explicitly in developing a computational method.

Computational Methods

In general, five methods can be used to compute the value measures:

1. Indexation: the original cost of the facility is updated by multiplying the cost with an index (reflecting price and/or technology changes).

2. Unit costing: the cost per capacity is multiplied by the capacity measure of the facility.

3. Regression: historical cost trends are extrapolated to the present and future.

4. Proportionment: a cost measure can be computed with respect to another cost which may be known or easier to compute.

5. Expert assessment: direct estimation using expert opinion.

The first four methods use mathematical formulas and arithmetic operations on numerical data. Therefore, conventional programming languages and techniques or a good integrated software developed for microcomputers (e.g., Lotus Symphony) could make it possible to automate any of these four methods.

The last method employs a knowledge base of experts in addition to a conventional data base. Therefore, to complete the computation, besides solving mathematical formulas, an inference engine is necessary to operate on the knowledge base and arrive at a logical conclusion. To achieve these tasks, the expert assessment method can be automated using artificial intelligence languages and expert systems techniques. (A commercially successful application has been documented for a similar situation; see paragraph 8 in the Appendix.)

Replacement Cost

Conceptually, any one of the five methods stated above can be used to compute RC. However, each has certain drawbacks.

Indexation

For this method, an index that reflects the annual changes in technology, requirements, standards, and prices is necessary. It is extremely difficult to develop such an index. However, if this difficulty can be overcome, this method would be very reliable and simple to implement using the following formula:

$$RC = (\text{Acquisition cost}) \times (\text{Index}) \qquad \text{[Eq 1]}$$

A readily available index is the *Engineering News Record* construction cost index, which is currently used by the Army.

Despite the difficulty of this method, it may be a very worthwhile effort to develop an index of the type described above. Such an endeavor would help Army managers understand the evolution in technology, standards, and requirements over time. They would then be able to assess the effects of this evolution on facilities and plan accordingly. This prospective planning, rather than after-the-fact, retroactive planning, is recognized as being more effective.

Unit Costing

If the unit costs (e.g., $/sq ft) of currently built facilities are known, then these costs can be multiplied by the capacity of the existing facilities to determine RC:

$$RC = (\text{Unit cost}) \times (\text{Capacity of existing facility}) \qquad \text{[Eq 2]}$$

Three difficulties are associated with this method. First, for certain facilities (e.g., utilities), it is not clear what the capacity unit should be. Second, certain types of existing facilities are no longer constructed. Third, it is not clear how to incorporate the cost of support structures for a facility (e.g., a parking lot for an office building).

These difficulties are not necessarily insurmountable. However, it is not clear if it would be worthwhile to spend effort in alleviating the difficulties. It should be noted that several ad hoc approximations are possible in order to circumvent these difficulties and implement the method. Indeed, this was standard practice in the Army until 1980.

Regression

For a given facility category, the recent construction costs can be analyzed to develop a trend line. Using this trend, the current construction cost can be computed. From this point on, however, the unit costing has to be implemented.

The current costs computed using the regression method will not have the third difficulty mentioned for unit costing but will still suffer from the first two. Furthermore, the regression line developed in this way is not likely to be very robust.

Proportionment

It is plausible to assume that there is a time invariant relationship between the OFC and RC. That is, for a given type of facility, RC is either a constant amount less

than OFC or a certain percentage of OFC. Suppose, within a given facility category, OFC_i of a facility that was built in year i can be estimated (as explained later in this chapter). Construction cost of that facility is known and is denoted by RC_i. If a linear relationship between them in the form of either:

$$RC_i = OFC_i - r$$

or:

$$RC_i = r \times OFC_i$$

can be established, and if the constant r can be shown to be invariant over time, then clearly:

$$RC_{\text{current year}} = OFC_{\text{current year}} - r \qquad \text{[Eq 3]}$$

or:

$$RC_{\text{current year}} = r \times OFC_{\text{current year}} \qquad \text{[Eq 4]}$$

The advantages and drawbacks of this approach will be discussed when OFC estimation is explained later in this chapter.

Expert Assessment

Besides the technical expertise required to implement this method, it is essential to know the Army's current policies and practices in designing and constructing current versions of the existing facilities. This knowledge base may not be well defined; that is, most rules within this pool of knowledge will be policy-related, hence subjective and, in many cases, loosely defined. The most significant source of the subjectivity, introduced at the design stage of a facility, is in resolving the cost-performance tradeoff. It is not clear, for example, if the Army should build low-cost temporary buildings that can be replaced frequently or higher cost buildings with longer life expectancies. Presumably, a comprehensive, accurate life-cycle cost analysis can provide an answer to this question. However, qualitative factors and future uncertainties will continue to make the knowledge base of such an analysis ill-defined. Research dealing with these knowledge bases is in progress but has not yet produced readily usable results.

In summary, indexation unit costing and proportionment are potentially useful methods for computing RC. Unit costing can be used readily with certain ad hoc approximations. Indexation probably would yield more reliable figures if a good index were developed. In addition to the quality of RC thus computed, such an index would provide significant managerial insight for facilities planning and management. Among the three potential methods, proportionment probably is the most desirable, if OFC is readily available. This method will allow managers to track technology in addition to computing RC. However, as discussed below, computation of OFC is a major undertaking.

Optimal Facility Cost

Recall that OFC is a hypothetical figure representing a norm or an ideal facility cost. Thus, there is neither historical nor current data that can form the basis of estimating OFC. The only method that can be used to develop a base cost is expert assessment. To implement an expert assessment, the following knowledge is needed:

- Functional purpose of the facility
- Requirements and standards
- State-of-the-art technology.

(An expert assessment with similar objectives has been implemented successfully; see paragraph 8 in the Appendix.)

An inference mechanism can act on this knowledge base to synthesize the design of an optimal facility configuration. Finally, using a data base that contains vendor-provided component costs, the OFC can be computed. This process is depicted in Figure 2.

The procedure just described has to be implemented at least once for each category of facility to establish a base OFC. In subsequent years, this base cost can be updated either by using the indexation method or by repeating the expert assessment. If indexation is chosen, it will be necessary to develop an index reflecting the changes in requirements, standards, and technology over time. The advantages and drawbacks of developing such an index have been discussed.

At this point, it is important to note the significance of determining an OFC figure. This figure will establish a norm against which "relative value" of existing facilities can be developed. As discussed earlier, the value concept is a relative one. For instance, had there been a market, a value would have been assigned to a property by observing similar properties' prices or costs in the market. In the absence of such comparison bases, a norm that is least distorted by human subjectivities and variances in actual practice is the most desirable base against which the relative value concept can be developed.

The expert assessment of OFC does not suffer the same drawbacks as that for RC. As discussed above, the RC assessment is ill-defined, mainly because subjective policies must be introduced to resolve the cost-performance tradeoffs. In contrast, OFC is a hypothetical figure that depends on the requirements and technology, but not on the economic policies. Therefore, OFC is determined based on technical experts' design recommendations. Clearly, these experts may not agree; however, their conflicts are much easier to resolve than those arising from policy considerations.

An automated assessment procedure for determining OFC could be developed (Figure 2) using current artificial intelligence/expert systems technology. Thus, OFC could be determined every year for each facility category through minimal staff time and effort. Furthermore, an automated system would be least susceptible to human judgment inconsistencies and could provide uniform measures across the facilities and over a time horizon. Indeed, in a number of fields it has been demonstrated that an automated system can outperform human judgment over time, mainly due to the inherent inconsistencies within the judgment (see details in paragraph 9 of the Appendix).

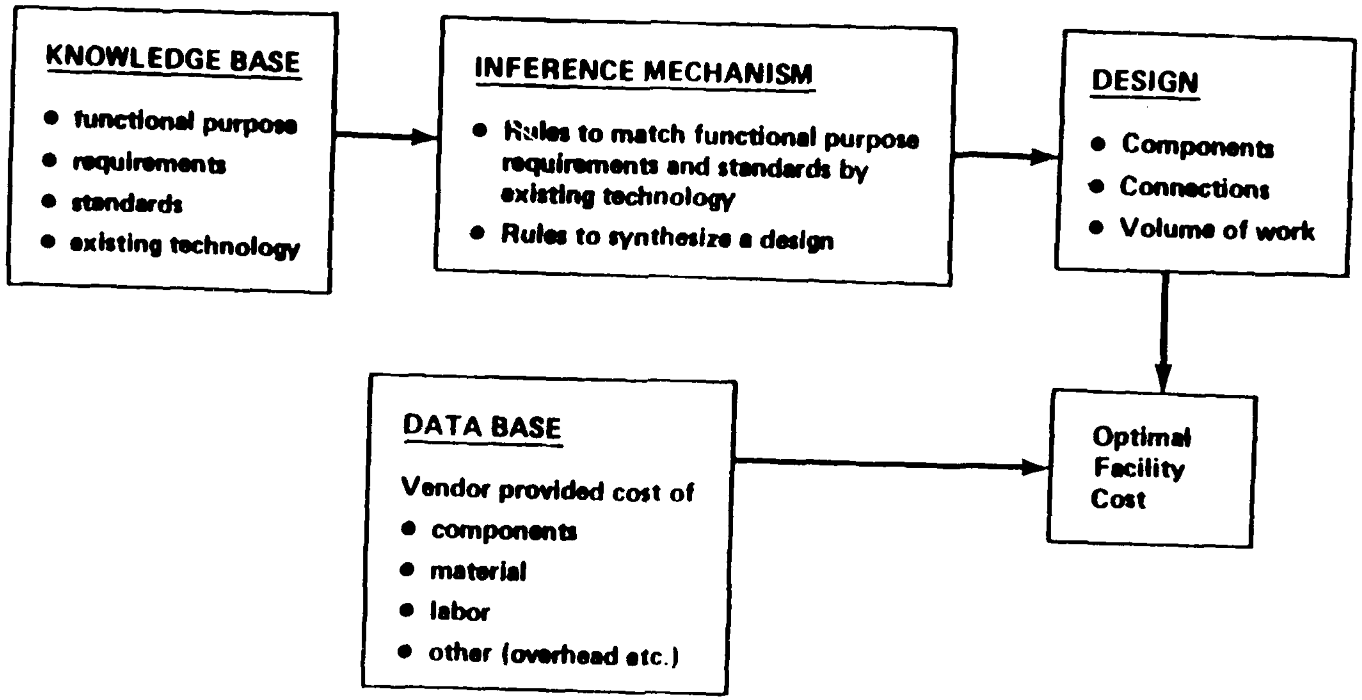

Figure 2. Expert assessment method of computing OFC.

In addition to forming a norm, the expert assessment procedure can be used for technology assessment and forecasting (see the Appendix, paragraph 10), and their cost implications. This knowledge can be a significant input into the process of planning future facilities.

Reproduction (Duplication) Cost

Of the four value measures identified, DC probably is the most straightforward to compute. The indexation method can easily be applied to update acquisition and renewal costs that contribute to the betterment of a facility:

$$DC = [\text{Acquisition Cost} \times \text{Index (1)}] + [\text{Renewal Costs} \times \text{Index (2)}] \qquad \text{[Eq 5]}$$

Indexes 1 and 2 vary only by the year in which the respective costs occur.

The major shortcoming of the above method is the possible inaccuracies in recording renewal costs. There are indications that, since certain renewal costs are typically high, if funding for them is not available, then M&R funds are used. Renewal is then achieved over a time period, with smaller amounts spent every year. If this practice is common, DC as computed above will not be accurate, but will underestimate the actual DC. There seems to be no way to overcome this drawback.

Value in Use

VU, also known as "value for continued use," reflects the present worth of future benefits that a facility has for the current user. Assuming that the cost of a new facility is equal to its VU, as the facility ages, its VU decreases by the accrued physical and functional depreciation. Depreciation, on the other hand, is perhaps one of the most controversial topics because of the inherent difficulties of measurement. Some simplistic approaches to depreciation, such as the straight-line approach, are well known but hard to defend.

VU is a subjectively defined relative value. The ambiguity of this value, however, can be partially eliminated if it can be computed relative to a well defined cost measure. Compare these two statements: "the VU I assign to the pine tree in my backyard is $100" and "the VU of the pine tree in my backyard is 20 percent more than a new small tree." While the first statement reflects a totally arbitrary value, the second provides a reference or base on which the value is defined. Several alternative bases or reference costs can be used in computing VU.

DC as a Base

If in the original functional use has not changed, a facility's VU will be its DC less accrued physical depreciation. In addition, if the facility has been properly operated, maintained, and repaired (assumption 2 in Chapter 2), then:

$$VU = DC - \text{Incurable physical depreciation} \qquad \text{[Eq 6]}$$

This formula reduces the depreciation estimate to only one component: incurable physical depreciation. The formula, however, does not apply to facilities used for a purpose other than that for which they were initially designed.

RC (or OFC) as a Base

RC is the cost of a newly acquired facility. What is the difference between this RC and the VU of an existing facility with comparable capacity and function? Stated another way, how much would the Army be willing to pay in order to have a newly acquired facility instead of the existing one? The answer will be subjective, but so is the "value" in general and VU in particular. Similar remarks can be made by replacing RC with OFC.

5 CONCLUSIONS AND RECOMMENDATIONS

Facility managers need a well defined algorithm to determine a "value measure" for their real property and facilities. However, it has been noted that "rote methods will often completely miss the goal [and] there is no single correct method to appraise." Therefore, this report has focused on fundamental concepts that can be used in developing the most appropriate value measure computational algorithms for each specific purpose. Only after further development will statements such as "2 percent of the facilities should be replaced annually" and "M&R costs are predicted to be x percent of the total 'value' of the facilities" have meaning.

Four value measures with potential application to the Army were identified: RC, DC, VU, and OFC. An analytical assessment of these measures showed that the first three are identical when the facility is new. As time passes, these measures are affected in different ways by changes in technology, requirements, standards, policies, prices, and depreciation. In addition, interrelationships among the measures were found to have the following implications for management:

1. (OFC - RC) reflects the gap between existing state-of-the-art technology and the implemented technology.

2. DC remains constant as long as the original facility receives no physical alteration.

3. If a facility is used for a purpose different than its initial one, DC becomes meaningless.

4. In general, the result of (RC - DC) reflects the incurable as well as curable functional depreciation.

5. Right after the time of renewal, the result of (RC - DC) reflects the incurable functional depreciation.

6. (DC - VU) reflects the functional and physical inadequacies of the facility according to its current use and compared with the initially intended use.

The study has proposed five ways of computing the four value measures. As stated above, there is no single correct method. However, the methods assessed in this study satisfy two requirements necessary for a management tool: logical consistency and computational accuracy.

Based on these findings, recommendations are listed below in the proposed order of priority (and, to a degree, in the order of difficulty):

1. Compute reproduction (duplication) costs (DC) of existing facilities using Equation 5 (Chapter 4). In this equation, renewal includes improvements in the existing facility but excludes M&R. Indexes 1 and 2 can be obtained from the Building Construction Indexes published by the *Engineering News Record*. As computed, DC can provide:

- A basis for estimating M&R costs
- An approximation to the value in use

- The trend in growth of facilities

- A base for renewal outlays.

2. Develop an expert assessment procedure (see Figure 2) for estimating an optimal facility cost (OFC). This value measure is a hypothetical figure that provides an objective ideal norm for a given facility. As such, it can serve as a base cost to obtain relative value measures.

3. Compute RC using Equation 3 or 4 with OFC as the base. Coefficient r can be obtained from the historical relationship between OFC and RC. The coefficient can be further calibrated by computing (whenever possible) RC using the unit cost method as well (Eq 2 in Chapter 4). RC can be used for the following purposes:

- (RC-DC) of an existing facility approximates the facility's functional deficiency

- Meaningful renewal policies can be developed to keep (RC-DC) below a certain level

- RC itself is an essential input to renewal and relocation policy processes

- When DC cannot be used meaningfully (for facilities that have undergone a change in function), VU can be computed instead, based on the RC value.

The use of two or more value measures and computational methods for appraising a given property is common practice in the real property appraisal field (e.g., for insurance and tax assessment--see the Appendix). Appraisal of the Army's properties should be given similar effort. Such an undertaking not only will serve the purposes discussed above, but offers an additional benefit in that the process of determining these value measures can reveal important management strategies.*

The findings in this study suggest that a comprehensive effort to evaluate Army facilities is well justified to (1) understand the evolution of cost over time; (2) improve life-cycle cost analyses; and (3) have effective control on the condition of these multibillion dollar assets.

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*It is only recently that large organizations have started to recognize the significance of effectively managing their real property, as recent *Harvard Business Review* articles indicate (see paragraph 6 in the Appendix).

APPENDIX:

NOTES ON THE LITERATURE SURVEY

The results from different disciplines (accounting, appraisal, cost engineering, building sciences, etc.) were surveyed. Sources that were particularly useful to preparation of this study are summarized below.

1. In 1976, the American Securities and Exchange Commission (SEC) announced regulations that require certain companies to disclose replacement cost data to show that these companies are properly valuing their real property and other assets. In *Staff Accounting Bulletin No. 7*, 1976, SEC defined replacement cost as "the lowest amount that would have to be paid in the normal course of business to obtain a new asset of equivalent operating or productive capability." Later, the SEC withdrew this requirement when the Financial Accounting Standards Board (FASB) published *Financial Reporting and Changing Prices*, FAS No. 33, September 1979. This publication provided companies with standards that offered greater flexibility in computing the value of assets. The FAS report evaluates the following property measurements: historical cost, current reproduction cost, current replacement cost, net realizable value, net present value of expected future cash flows, recoverable amount, current cost, and value to the business. The report is very useful in explaining the merits of different value measures. At present, the report is being revised.

2. The seminal book on the theory and practice of appraisal is *Appraisal Principles and Procedures*, by Henry A. Babcock, American Society of Appraisers, Washington, DC, October 1980 (originally published in June 1968). The book is an extremely valuable source, with extensive, meticulous coverage of the appraisal field. Different replacement cost and value concepts are treated rigorously.

3. One of the two professional societies in the appraisal field is the American Society of Appraisers located in Reston, VA. The society publishes an aperiodical journal called *Valuation*. The following papers from this journal are useful in describing value measures:

"The Opinion of the College on Definitions, Concepts and Principles of Appraisal Practice," June 1975, pp 85-87.

F. M. Babcock, "Basic Valuation Principles Revisited," June 1975, pp 8-22.

E. M. Rams, "The Concept of Substitution in the Property Valuation Process," November 1981, pp 80-83.

M. B. Hodges, Jr., "Mass Appraisal of Investment Class Properties," November 1981, pp 44-66.

W. R. Kellough, "Towards a Methodology of Valuation in Urban Renewal Areas," November 1979, pp 50-59.

R. M. North III, "Building Replacement Cost Estimating for Non-Professional Estimators," November 1982, pp 128-138.

4. The other major professional society in the appraisal field is the American Institute of Real Estate Appraisers, located in Chicago, which publishes *The Appraisal Journal*. The following papers are selected from this journal:

M. J. Derbes, Jr., "Is the Cost Approach Obsolete," October 1982, pp 581-590.

T. V. Grissom, "Value Definition: Its Place in the Appraisal Process," April 1985, pp 217-225.

D. J. Hartman, "Industrial Real Estate: Value in Use or Value Abuse," April 1976, pp 217-225.

D. J. Hartman, "Industrial Real Estate: Estimating Value in Use," July 1979, pp 340-350.

D. J. Hartman and M. B. Shapiro, "Depreciation: Incurable Functional Obsolescence and Sequence of Deductions," July 1983, pp 408-414.

H. P. Lombardelli, "Random Thoughts on the Predictability of Industrial Real Estate Values," January 1978, pp 34-43.

A. Reynolds, "Current Valuation Techniques: A Review," April 1984, pp 183-197.

T. Skogstad, "Valuing Industrial Real Estate in Use," July 1976, pp 428-434.

T. R. Smith, "New Dimensions in Appraisal Technology," January 1974, pp 47-61.

D. H. Treadwell, "Value in Use in Perspective," April 1978, pp 223-229.

5. The American Association of Cost Engineering (AACE) publishes transactions of its annual meetings. In 1977, right after SEC published the requirements on replacement costs (see paragraph 1 above), the AACE had a special section in its meetings on "replacement cost." The following papers are selected from *Transactions of 21st AACE Annual Meeting*, Milwaukee, WI, June 26-29, 1977:

W. B. Blackwell, "Replacement Cost and Multidimensional Capacity," pp 216-219.

E. C. Goodier, A. D. Holmes, and W. B. Blackwell, "Replacement Cost and Indexation," pp 212-215.

A. M. King, "The Relationship of Replacement Cost Information Required by the SEC and Internal Capital Expenditure Budgeting," pp 208-211.

T. Skogstad, "Valuation of Operating Industrial Manufacturing and Process Plants," pp 220-224.

6. Harvard Real Estate, Inc., which manages Harvard University's commercial and residential properties, conducted a survey of 300 U.S. companies to identify how they manage their real estate. The results and convincing arguments in favor of more effective management of real property are reported in:

S. Zeckhauser and R. Silverman, "Rediscover Your Company's Real Estate," *Harvard Business Review*, January-February 1983, pp 111-117.

7. The following study contains an extensive survey of literature pertinent to buildings maintenance, repair, and renewal:

O. Coskunoglu and A. Moore, *An Analysis of the Building Renewal Problem*, Technical Report P-87/11/ADB112755, U.S. Army Construction Engineering Research Laboratory (copies are available from the National Technical Information Service, Springfield, VA).

8. Chapter 4 suggested using a knowledge-based system for automated expert assessment of the optimal facility cost (OFC). OFC can be computed after the optimal design is determined. At present, Digital Equipment Corp. is using a computerized expert system called "XCON" to help configure VAX computer systems according to customer-specific requirements. XCON (short for "expert configurer") was initially developed by Professor John McDermott of Carnegie-Mellon University. A simplified description of XCON is given in the following article. (This expert system is one of the first commercially successful artificial intelligence applications. Therefore, almost any book on artificial intelligence and on expert systems will briefly describe this system):

A. Kraft, "XCON: An Expert Configuration System at Digital Equipment Corporation," *The AI Business - Commercial Uses of Artificial Intelligence*, edited by P. H. Winston and K. A. Prendergast, MIT Press, Cambridge, MA, 1984.

9. In this landmark study, Bowman of MIT demonstrated that decision rules derived from a manager's own average behavior may actually yield better results than the manager:

E. H. Bowman, "Consistency and Optimality in Managerial Decision Making," *Management Science*, Vol 9, 1963, pp 310-321.

Since this paper was published, several researchers have verified that linear statistical models nearly always outperform human decision-makers. This result occurs partly because models are consistent and human decision-makers are not. Even more striking is the finding that models of decision-makers outperform the decision-makers themselves. Again, lack of consistency in human judgment is a possible explanation. Replacing decision-makers with models of themselves, i.e., "boot-strapping," would be an effective and efficient, although somewhat appalling, approach.

10. Some of the methods proposed in Chapter 4 require technology measurement and assessment. There is extensive research ongoing in the area of technology measurement, assessment, and forecasting. The journal *Technological Forecasting and Social Change* publishes high-impact research in this area. Two special issues have been dedicated to technology measurement and assessment: Vol 27, Nos. 2 and 3, 1985. The articles in these issues report the state of the art. An earlier paper published in the same journal proposes a method of comparing two items--one more expensive than the other but also more advanced in technology. Bell Canada has been experimenting with this method to normalize the replacement costs of its buildings. The method was explained in:

M. O. Stern, R. U. Ayres, and A. Shapanka, "A Model for Forecasting the Substitution of One Technology for Another," Vol 7, 1975, pp 57-79.

11. The following two books contain several detailed case studies for appraising real property. Of particular interest are the case studies on appraisal of special-purpose properties such as university dormitories, churches, and hospitals:

E. J. Friedman (Ed.), *Encyclopedia of Real Estate Appraising*, 3rd ed., Prentice-Hall, Englewood Cliffs, NJ, 1978.

P. C. Robinson, *Complete Guide to Appraising Commercial and Industrial Properties*, Prentice-Hall, Englewood Cliffs, NJ, 1977.

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